A Framework For Continuous And Comprehensive Assessment Of Learners At The Undergraduate Level Of Studies

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ABSTRACT

The expected and essential outcome of any teaching-learning process is, to transform the learner from a novice to an expert, which essentially means a transformation of the learner, from a student to a scholar. The present-day higher education necessitates a significant advancement and refinement in the teaching-learning and Assessment methodologies, to keep pace with the global competitiveness expected to be achieved by learners even at the undergraduate level. Apart from the need for regular need-based revision of the course content, structure and innovations in curriculum development, appropriate and acceptable Assessment of the Learner knowledge acquisition throughout the course, is a vital component of the learning process, especially at the undergraduate level of Tertiary Education. **C**ontinuous and **C**omprehensive **A**ssessment (**CCA**) of Learners – both summative and formative, is expected to facilitate bridging of the learning-gaps and is aimed at integration of knowledge domains. The challenge is in designing assessment tools which intend to test the learners progressive indexing of knowledge. Focus should be on prior and current knowledge level of the Learner at the entry level, and thereafter, on the conceptual understanding and application of concepts to problem-solving during the course of the undergraduate studies, culminating in a higher level of mathematics for content development and interpretation at the culmination of the end Semester. The three categories of assessments lay a pathway to the three knowledge levels, namely - Factual, Conceptual and Procedural.

In this article, the authors enumerate the inadequacies of the present system of CCA under the semester system presently prevalent in the domain of physical sciences, in the Karnataka State, more-specifically related to the undergraduate studies. Through statistical testing measures used in data interpretation, a more reliable assessment framework is proposed, which helps the instructor to identify the misconceptions and/or learning gaps in the students, as also one which initiates a continuous and comprehensive testing all, the three lower-order cognitive skills and the first higher-order cognitive skills as per the revised Bloom's Taxonomy of Anderson and Krathwohl.

Keywords-Continuous Comprehensive Assessment, framework, factual knowledge, conceptual understanding, statistical analysis.

INTRODUCTION

Education is a process that fosters a transition between some initial state of student's knowledge and some desired final state. The goal of education at the undergraduate level is to enable students to engage with the course curriculum, to understand the learning processes, to think analytically & critically, to problem-solve, to use resources optimally & use technology effectively. In the context of course-content learning, it is essential that the course structure is relevant to the present day and the curriculum encompasses effective teaching methods, tools and resources. The teaching-learning processes need to be directed towards initiation of knowledge organisation and access, either in a known context or a new context.

Science learning comes with several complexities like understanding symbols, laws governing phenomena & concepts, being able to switch between multiple representations, navigating through the rigour of mathematics and acquiring problem-solving skill –sets.

According to E. F. Redish,[1] it is appropriate to characterize the knowledge along the axes of robustness (how broadly the knowledge is activated in a variety of situations), degree of compilation (the extent to which complex knowledge can be applied as a unit in working memory), and level of integration (how much diverse knowledge is tied together). F. Reif and Joan I. Heller [2] state the significance of knowledge organisation to facilitate efficient information retrieval and physics problem solving. Van Heuvelen [3] presents a knowledge hierarchy chart with one idea (Forces causing motion) as the basis for diverse applications in Newtonian mechanics. An effective learning strategy is to organise the knowledge which builds the foundation to be adept at learning.

Learning with understanding to apply and analyse is central to all knowledge- building and organisation. The assessments are to be continuous for summative and formative purposes and comprehensive for knowledge organisation.

However, learning, in the present-day scenario, typically happens without understanding.

The current method of assessing the outcome of content-learning is through tests and assignments. The question that needs to be addressed is: what is it that is being "tested" through the tests and assignments? Apparently, the purpose of the assessments is to check whether or not disconnected chunks of knowledge can be recalled and reproduced by the learners. They lack adequate "testing" on facets of conceptual understanding, knowledge-application and problem-solving (the latter is with reference to physical sciences). The focus of present –day assessments is as shown in fig 1.

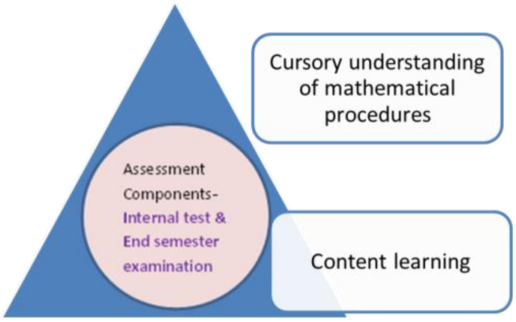


Fig 1: Objectives of current methods of assessment

As the assessments do not adequately address the testing of learners' knowledge-base and problem-solving skills, there is a need for Continuous and Comprehensive Assessment (CCA). Fig 2 shows the objectives of CCA with the additional dimension of critical thinking.

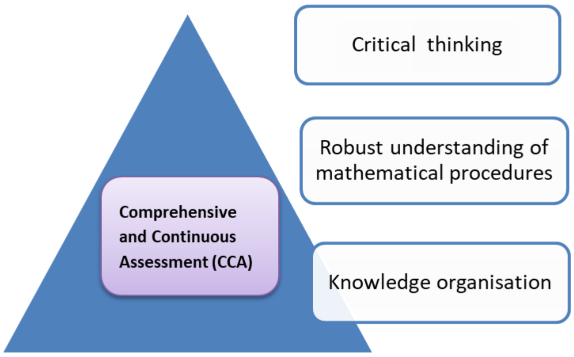


Fig 2: Objectives of continuous and comprehensive methods of assessment

PROPOSED FRAMEWORK FOR CCA

With focus on the growth of a learner in acquiring concrete knowledge and progressing towards abstract knowledge, we propose an assessment framework that is comprehensive and continuous at the undergraduate level. Designing assignments and tests that foster a deep insight to student learning is a challenge. J M Buick[4] considered a range of physics assignment questions and categorized them by the level of knowledge and understanding which is required for a precise answer and proposed a taxonomy to aid classification of questions.

In this study, we propose an assessment pattern based on Anderson& Krathwohl taxonomy (revised Bloom's Taxonomy) [5]. The matrix in this taxonomy is in line with the expected outcomes of a CCA. Fig 3 shows the framework of the CCA based on Anderson& Krathwohl taxonomy.

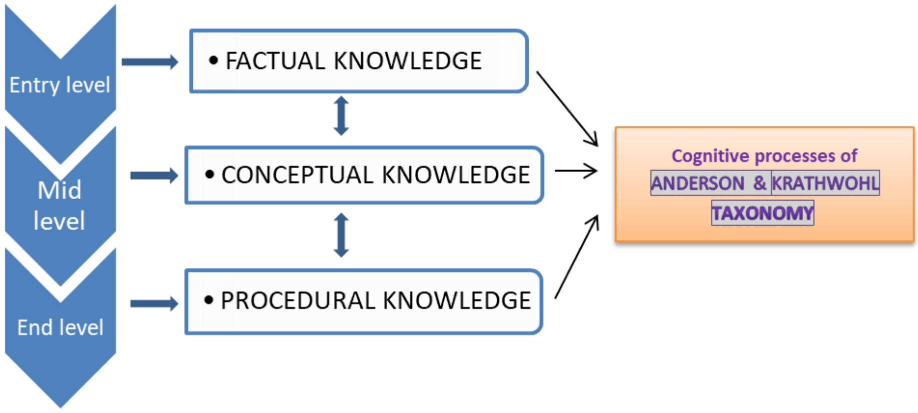


Fig.3 Proposed framework for CCA

Fig 4 illustrates the proposed assessment format at all levels of the course.

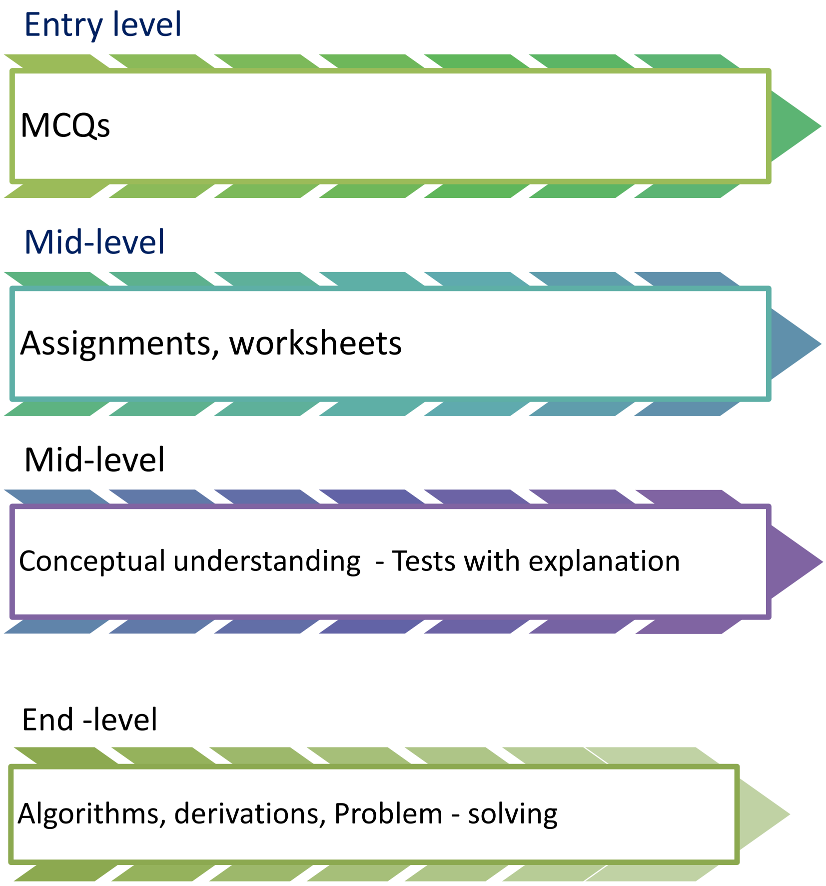


Fig 4

To test the students on factual knowledge on the first four cognitive processes, we have chosen the MCQ format. Our hypothesis is that students may have difficulties in the cognitive domains of applying and analysing of factual knowledge while it may not be so in the cognitive domains of remembering and understanding. Though MCQs do not test the conceptual understanding at a deeper level, the advantage is that the tests can be administered to a large number of students and designed on multiple topics. The analysis of the data is as significant as a well-designed test. Using the information obtained from statistical test measures and techniques, physics instructors can review the multiple-choice test.

PREVIOUS RESEARCH

Design and development of concept inventories which are education-related diagnostic tests in physics have been instruments to assess students' conceptual knowledge, elucidate misconceptions and identify learning difficulties on several facets. In 1985 Halloun & Hestenes [6] introduced a "multiple-choice mechanics diagnostic test" to examine students' concepts about motion in Newtonian mechanics. The Force Concept Inventory (FCI) (Hestenes.et.al [7]) was designed to assess student understanding of the Newtonian concepts of force. Thereafter, additional validated assessment tools were developed in various branches of physics. Physics education researchers have developed concept inventories, principally in the MCQ format, which test the change in the conceptual understanding of thermodynamics /Statistical Content knowledge of students from the beginning and to the end of an introductory thermodynamics course. The tests include wide-ranging topics: temperature, heat transfer, ideal gas, phase change, thermal properties of materials, first law of thermodynamics (Wattanakasiwich, P.et.al.[8], Yeo, S., & Zadnik, M. [9].

METHODOLOGY

Heat and Thermodynamics is a branch of Physics to which the students are introduced in I Year Pre-University Course. The UG students learn thermodynamics, fairly exhaustively in the I Semester BSc course and further at PG level. We intend to test the factual knowledge connected to cognitive processes in thermodynamics at the entry level (a couple of weeks into their BSc course), conceptual knowledge at mid-level and procedural knowledge at the end level.

Ding & Beichner [10] introduced the classical test theory that is used to analyse multiple-choice test data. The statistical data analysis helps us in identifying the difficult test items, discriminating the low performance group from the high-performance group and knowing individual item reliability through the three measures: item difficulty level P, discrimination index D, and point biserial coefficient rpbi. The test measures, Kuder-Richardson reliability index (r test) and Ferguson's delta ∂ evaluate a test in totality (rather than evaluate the individual test items)

The test analysis facilitates the instructor to identify students' errors and address the same in teaching-learning interviews which is one of the two components of formative assessment. The mid-level assessment is to test the conceptual understanding and the end-level on application of mathematical knowledge. The CCA as per the suggested frame work would enable the advancement of the learner from an initial stage of assimilating concrete knowledge to acquiring abstract knowledge.

PARTICIPANTS AND METHOD

As a first step towards CCA, an MCQ test (pilot test) on heat and thermodynamics is administered to 125 students who have opted for PCM, PME & PMCs as core subjects offered at the BSc level, with equal weightage on the three subjects. The MCQ test has 30 items (which are compiled) with four options and a single correct option. The maximum time allotted is 55 minutes.

In this study, the responses to MCQs are analysed qualitatively and quantitatively. The percentage of the students selecting a particular option and statistical test measure for the individual test –item in MCQ format which is the item –difficulty index and discriminatory index are evaluated. The data analysis enables to know where the students are positioned on cognitive domains of factual knowledge. It further facilitates us to design the assessments which test the conceptual understanding and the mathematical procedures.

RESULTS AND ANALYSIS

The responses to the 30 test-items on rudiments on heat and thermodynamics were analysed qualitatively and quantitatively.

1. Item –wise analysis

The percentage of correct answers item-wise was determined. Fig 5 shows the percentage of correct responses.

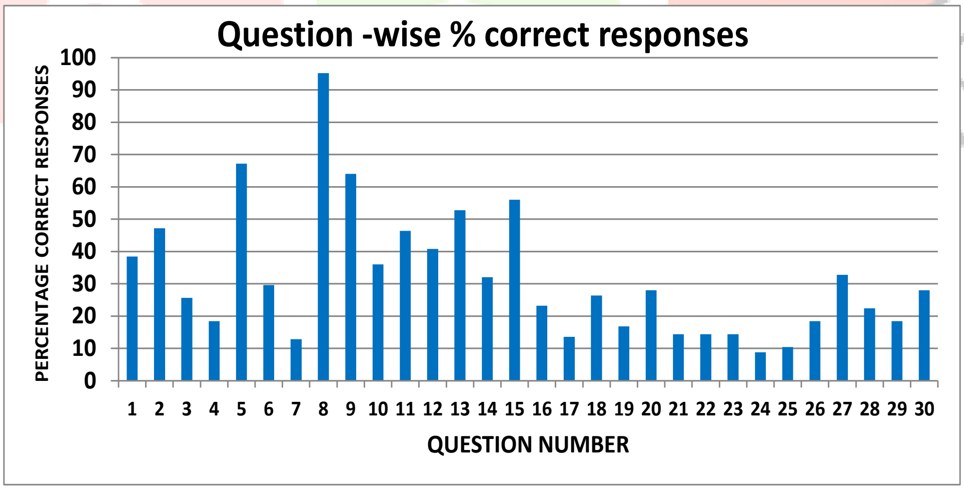


Fig 5. Percentage of correct options –item wise

The Item difficulty is a measure of the easiness of an item (although it is ironically called “item difficulty” level) and is defined as the proportion of correct responses, $P=N_1/N$. Here N_1 is the number of correct responses and N is the total number of students taking the test. In order to investigate student performance on items with a range of cognitive complexity, the item difficulty index is calculated for the items. As shown in Table 1, sixteen of the test items have a difficulty index < 0.3 which suggests that the students have a difficulty in grasping the defining characteristics of basic knowledge of heat and thermodynamics.

Question no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Item diff index P	0.38	0.47	0.26	0.18	0.67	0.3	0.13	0.95	0.64	0.36	0.46	0.41	0.53	0.32	0.56
Question no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Item diff index P	0.23	0.16	0.26	0.34	0.26	0.14	0.14	0.15	0.09	0.1	0.18	0.33	0.22	0.18	0.28

Table 1: Item difficulty index

2. Overall test analysis: The total score of each student on a maximum score of 30 was marked using the answer key.

The average score, median, mode and standard deviation were evaluated as 9.57, 9, 8 and 3.48 in the order. The overall analysis furthermore, consisted of evaluating Kuder-Richardson reliability index. Kuder-Richardson reliability r_{test} measures the internal consistency of an entire test. A widely accepted criterion is that a test of reliability higher than 0.7 is considered reliable for group measurement. The reliability index for the test on heat and thermodynamics is 0.57 which is lower than the accepted criterion of r_{test} being greater than 0.7.The test proved to be fairly effective in assessing the student group.

3. Investigation of select -test items classified as per Anderson's & Krathwohl Taxonomy

We catalogue the questions in the factual knowledge domain as shown in Table 2 and analyse the responses of five select questions Q2, Q6, Q13 Q15 & Q16.

Knowledge dimension	1.Remember	2.Understand	3.Apply	4.Analyse	5.Evaluate	6. Create
Factual	Q2	Q13, Q15	Q6	Q16	----	---

Table 2: Matrix of Anderson - Krathwohl Taxonomy for select test items

A) Q2 tests the students on remembering the value of absolute zero temperature.

2. The absolute zero temperature is taken as

a)-237 °C b)237 °C c) -273 °C d) 273 °C

The percentage of students who chose the correct option c) is 47% which is not so high on a task of recollecting the value of absolute zero temperature. Of those who did not select the correct option, 45% chose the value 273^0C, ignoring the minus sign. This may be attributed to the fact that students add 273^0C to convert a numerical value of temperature from degree celsius to temperature in kelvin and have used the same understanding in selecting the value 273^0C. About 6% has chosen the option a) and 1% has chosen option b). There is not as much confusion in the value of absolute zero temperature as there is in the sign of the value of temperature. The item difficulty index (Ding [10]) for Q2 is 0.47.The item discriminatory index D (Ding[10]) is computed to be 0.452. The value of D suggests that the test item discriminates between the high performers from the low performers.

The figure 6 shows the percentage of responses option-wise. (NA denotes Not Attempted in the bar graphs)

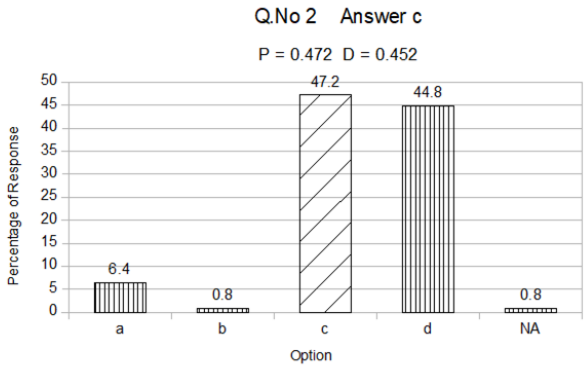


Fig 6

B) Q13 requires the students to choose the option which describes an isothermal process.

13. In an isothermal process
    a) there is no change in volume
    b) there is no change in pressure
    c) there is no change in temperature
    d) there is a change in thermal energy

Fig 7 shows the percentage of responses option-wise for Q13

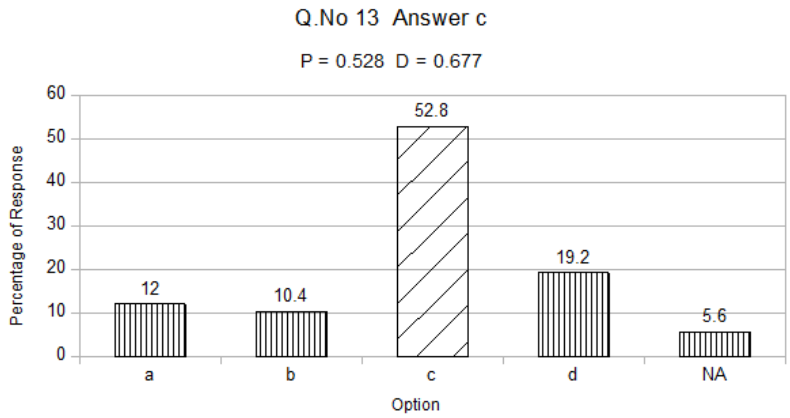


Fig 7

Item Q15 is a question on the understanding of an adiabatic process. The students require selecting the option that describes an adiabatic process.

15. In an adiabatic process
    a) there is no change in volume
    b) there is no change in pressure
    c) there is no change in temperature
    d) there is no exchange of heat energy between the system and surrounding

Fig 8 shows the percentage of responses option-wise for Q15

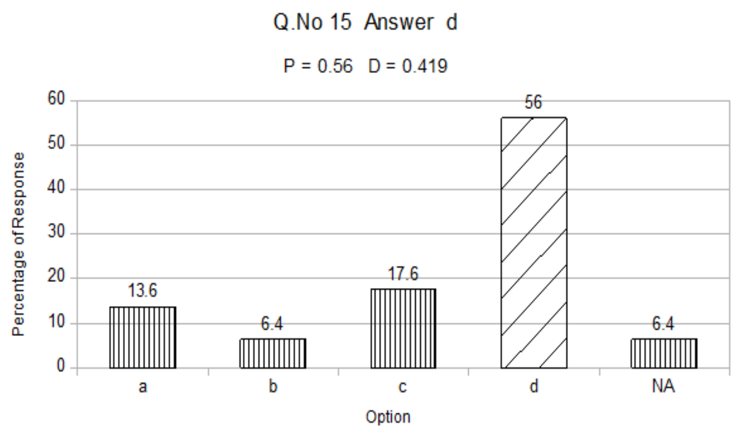


Fig 8

About 53% answered Q13 correctly and 56% answered Q15 correctly. The two test-items have nearly the same difficulty level. This suggests that a confusion related to the description of the thermodynamic processes exists in the minds of the students.

C) The task in Q6 comprises of selecting the statement which is true of the relation between the two molar specific heats of an ideal gas.

6. For an ideal gas, if C_p denotes the molar specific heat at constant pressure and C_v denotes the molar specific heat at constant volume; which of the following statement is true?

a) C_p is always less than C_v.
b) C_p is always greater than C_v .
c) C_p is equal to C_v .
d) C_p can be greater than or equal to C_v .

Fig 9 shows the percentage of responses option-wise for Q6

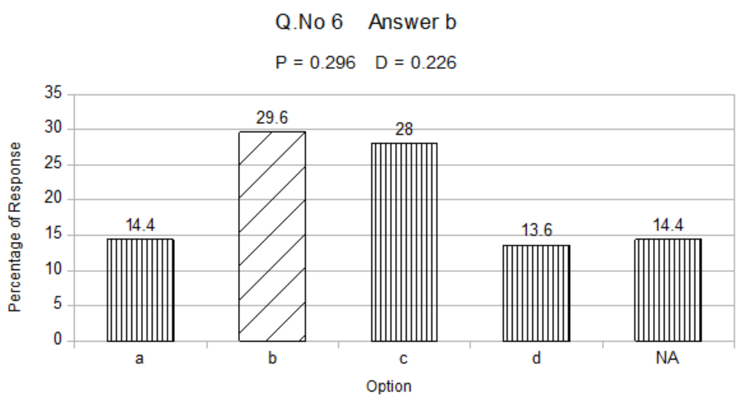


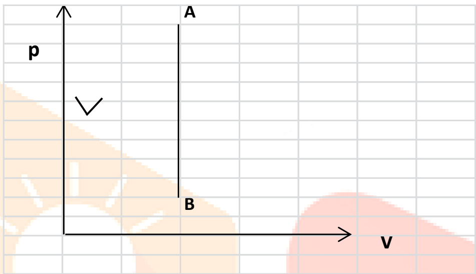
Fig 9

We list the task as the third cognitive process which requires use of the Mayer's relation or the ratio of specific heats of an ideal gas γ or analysis of the isochoric and isobaric process.

About 30% of the students chose the correct statement b). The low percentage of correct responses is indicative of the lack of students' ability to apply the factual knowledge related to the specific heats either through the mathematical relations $R=Cp- Cv$, $\gamma = Cp/ Cv$ or through applying the concept of heat required for the same change in temperature under constant pressure and constant volume conditions.

C) Q16 is a graphical question concerning an isochoric process. We index the question as the fourth cognitive process which is analysis of factual knowledge.

16. A system undergoes a thermodynamic process from a state A to a state B as indicated in the p-V diagram. Which of the following statements about the process is true?



a) The process is an isochoric process.
b) The process is an isobaric process.
c) Work done in the process is positive.
d) Work done in the process is negative

Fig 10 shows the percentage of responses option-wise for Q 16

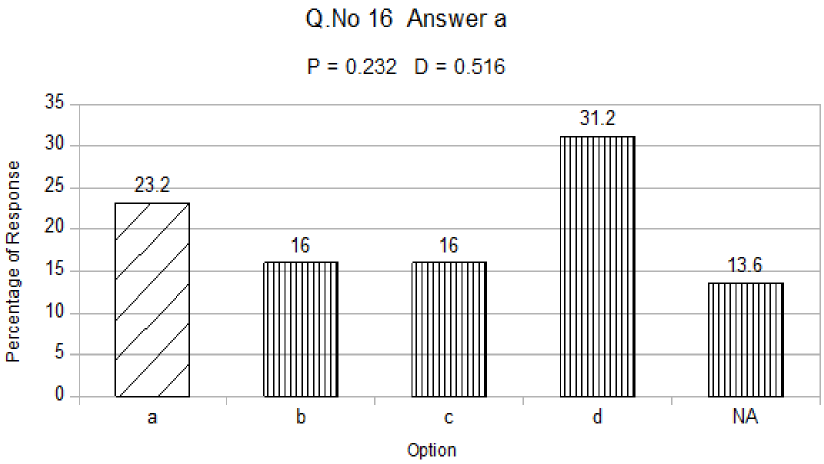


Fig 10

The difficulty index for item Q16 is evaluated as 0.23. This numeral suggests that it was a difficult question. Though seemingly it is a simple task, the response involves a three-step procedure: i) to 'read' the graph ii) to analyse the process in terms of change in volume and iii) to infer on the work done during the process.

The discriminatory index is 0.516 which suggests that the item proved to be a worthy question to discriminate the high performers and the low performers.

The response to the test item requires the understanding of an isochoric and an isobaric process. Alternatively, it requires the recalling of the equation for work W=PdV where dV is the change in volume. 47% of the students have chosen the option of work done, either positive or negative. This indicates their inability to distinguish the different thermodynamic processes. In addition, it also reflects the students' inability to 'read 'the information from the graph.

CONCLUSIONS

Firstly, this study elucidated the analysis of the heat and thermodynamics diagnostic test on three aspects: overall analysis, item-wise test analysis and select- item analysis; the selected items indexed using Anderson – Krathwohl Taxonomy. The investigation was both qualitative and quantitative. Heat and thermodynamics encompass a number of symbols, factual statements, principles and concepts which are required to comprehend the physical phenomena. The results of this study helped us identify the students' inadequacy of the factual knowledge of heat and thermodynamics which impedes their conceptual understanding and inability to navigate through the mathematical equations.

The analysis of the performance of the students clearly validates our hypothesis that new entrants into undergraduate course in physics will have difficulty in applying their knowledge in a given situation and analysing a given problem to solve the same. What comes as a surprise though is that the students seemingly have difficulty even in remembering and understanding basic and fundamental concepts.

Secondly, assessments and feedback mechanisms which foster knowledge organisation by repeated exposure to concepts and analytical techniques are central to the learning process.

Pedagogical practices that are adopted as per the proposed framework are intended to facilitate students to learn how to learn in addition to what to learn. Physics instructors need to develop taxonomies appropriate to pedagogical hierarchy.

FUTURE SCOPE

To address the inadequacy of factual knowledge, hand-outs can be prepared by the instructors and investigate the learning gaps through teaching –learning interviews.

Physics instructors need to assess the students' conceptual understanding and identify the essential skill sets to build a robust mathematical knowledge which is vital for problem-solving.

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